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that the place of observation should be taken as near as possible to the curved diametral arrow which lies across my two charts of the Earth in the *Monthly Notices* for June 1869 (plates 5 and 6). Most of the stations already dealt with are little affected by this condition; but, for observing retarded egress, all the Indian stations will be found (in this respect) far better than Alexandria. At Peshawur, for instance (a place already superior as respects coefficient of parallax and solar elevation), *Venus* will leave the Sun almost exactly at his uppermost point, whereas at Alexandria the point of last contact will be about 34° from the uppermost point of the Sun's limb.

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*A New Theory of the Milky Way.* By R. A. Proctor, B.A.

Sir W. Herschel's respect for existing analogies—a quality which is perhaps of all others the safest guide for the scientific explorer,—led him to adopt as the means of interpreting his noble series of star-gaugings the hypothesis that there is a general uniformity in the distribution of the stars through space. He adopted this hypothesis not from a conviction of its being actually true, nor even from the belief that it is approximately so, but simply because existing analogies seemed to render it probable, and because it formed a convenient basis for calculation. The existing analogies were those presented by the solar system. In this system, Sir W. Herschel recognised a number of discrete bodies, not equal indeed, but comparable *inter se* in magnitude; not uniformly distributed, but still not aggregated towards one or another part of the solar scheme. And making such modifications as seemed requisite in comparing a system not regulated by a vast central orb with a scheme like our solar system, it seemed likely to him that a general equality of magnitude, and a general uniformity of distribution, might be found to prevail among the members of the sidereal system.

We now know that the ideas which astronomers had formed of the solar system in Sir W. Herschel's day were very far indeed from being correct. We see in the solar system a complexity of detail, and a variety of form, structure, aggregation, and motion, which were altogether unknown a century ago. And I cannot doubt that if the view we have of the solar system had been presented to Sir W. Herschel, he would have adopted as the basis of his star-gaugings an hypothesis differing altogether from that of which he actually availed himself. He would have argued, that as, in the solar system, there are bodies like the planets, far surpassing the other members of the scheme in magnitude and in importance; as it contains zones of minute bodies, such as the asteroids and the satellites composing the rings of *Saturn*; myriads of meteoric systems, and countless thousands of cometic systems, so doubtless in the sidereal system there are many forms of matter. If the analogy of the solar system is to be our guide, we

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must look for suns equalling or surpassing our own in magnitude and splendour; for clusters and systems of minor suns, whose united mass may fall short of the mass of one of the primary stars; for aggregations of matter in portions relatively so minute as not even to be comparable with the small stars found in true star-clusters; and finally, for systems composed of materials, or at least of forms of matter, differing as widely from the substance of the suns, as the matter composing a comet does from the substance of the Earth or of *Jupiter*.

But, even independently of analogies such as these, his own series of observations led Sir W. Herschel to feel more and more doubt, as he proceeded, respecting the hypothesis which he had made the basis of his calculations. It is only necessary to compare the later papers he sent in to the Royal Society with the earlier ones, to find that views altogether inconsistent with his initial hypothesis were opening out before him. It was in those later papers that he spoke of star-groups in the Milky Way clustering towards opposite regions of the heavens; of stars arranging themselves into separate systems; and of the signs which the heavens present of the action of processes of aggregation, causing "the gradual dissolution of the Milky Way."

Sir John Herschel, also, in carrying out the system of star-gauging among the Southern stars, was led to notice many features which the hypothesis of a tolerably uniform distribution of stars could not satisfactorily explain.

Judged according to Sir W. Herschel's fundamental hypothesis, the sidereal system came to be regarded as forming a figure resembling that of a *cloven disc*, and the Milky Way was explained as being due simply to the greater extension of the system in the direction of the medial plane of this disc. Sir John Herschel, however, from his observations of the Southern heavens, was led to suspect that this theory was not strictly correct. He speaks in one place of certain evidence, according to which the Milky Way would come to be regarded as a flat ring seen edge-wise. And in many places he speaks of the difficulty of understanding certain features according to the views usually accepted.

It seems to me that the evidence collected respecting the Milky Way is sufficient to lead us to quite another view of its structure than that to which Sir W. Herschel was led by an hypothesis founded on the incomplete theories which astronomers in his day had formed respecting the solar system.

Let us regard the matter altogether independently of preconceived opinions, and judge simply as the evidence may seem to teach us.

In the woodcut, the outer figure represents the Milky Way according to the drawings and description of Sir John Herschel. The mode in which it is delineated needs no explanation.

Now in regarding this picture of the Milky Way, we are forced, I think, to the conclusion that neither the cloven-disc theory, nor the flat-ring theory, accounts satisfactorily even

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for the principal features of the Milky Way. For example, the great gap which crosses it in *Argo*, nearly in the widest part of the single branch, seems utterly inexplicable on either theory. There is no way of accounting for that gap if we are really supposed to view the Milky Way from a point within its figure, and that figure resembles—however roughly—either a cloven disc or a flat ring.

But let us pass to other features. Travelling towards the right from the gap, we come to the strange semicircular cavity


with a well-defined outline, which Sir John Herschel has described in such striking terms. A cavity of that figure is a remarkable phenomenon, and is surely inexplicable either on the flat-ring or cloven-disc theory. But the mere distinctness of the outline is one of the strongest possible proofs that the stars which form that portion of the Milky Way constitute a distinct clustering aggregation from which we are separated by an enormous and comparatively star-less interval.

We come next to the Great Coal-sack near *Crux*, almost opposite to which is a well-marked opening in *Cygnus*. There are

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also other strange openings through different parts of the Milky Way.

Now I cannot but think that an argument similar to that which Sir John Herschel has applied with so much force to the Magellanic clouds applies to the openings in *Crux* and *Cygnus*. He argues that because the Magellanic clouds approach roughly to the circular figure, therefore, in all probability, their real figure is that of a sphere: the chance is small that one of them is a cylindrical system seen endwise, but the chance that both are is altogether evanescent. Now applying the same principle to the Coal-sacks, we are led with equal certainty to the conclusion that these apertures are not cylindrical or tunnel-shaped openings seen endwise, but *if they are really openings at all* they are openings through a system which is not very much deeper—measured in the direction of the line of sight—than the greatest width of the aperture itself.

Judged in this way, the parts of the Milky Way which lie round a "Coal-sack" would have a roughly circular section, and not that enormous extension in the direction of the line of light, which has been assigned to them.

I cannot see that this argument is at all less sound or less effective than that which has been applied by Sir John Herschel to the Magellanic clouds.

There is another feature referred to, and I believe discovered, by Sir John Herschel, which is also full of meaning. I refer to the existence of narrow and sometimes convoluted streams of stars, branching out from the Milky Way itself. Sir John Herschel says of these that we ought to look on them as in all probability planes or scrolls of stars seen tangentially, and not as branch-shaped extensions bristling up from the general level of the Milky Way. And undoubtedly if the Milky Way really have a great extension in the direction of the line of sight, it is just that we should so regard these outlying streams. But if we judge of them without any reference at all to pre-existing theories, we are guided by strong arguments from probability to form a very different view. The chance that a plane system of stars, and still more a scroll of stars, should be turned so directly towards the Sun as to present to us the appearance of a straight or convoluted line or narrow stream of stars, is small indeed. The probability that several should be so situated may be regarded as evanescent.

Accepting these streams as having a roughly circular section, we are led to the conclusion that the Milky Way from which they extend has a similar section. In fact, as Sir John Herschel held these streams to be really planes or scrolls because (I assume) he assigned to the Milky Way a great lateral extension, so by inverting this argument I am led to believe that the Milky Way has not a great lateral extension (compared I mean with its thickness), because the streams extending from it have in all probability a section of roughly circular figure.



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Other arguments there are that space will not permit me to dwell upon here, which point in the same direction.

Now, of course, if the Milky Way forms in reality a stream of stars *amidst the sidereal system*, the appearance which it presents upon the heavens might be expected to afford some information as to the shape of that stream, or at least of that portion which is cognisable by us. It must be admitted, however, that the problem of interpreting this wonderful stream is one of enormous difficulty. Perhaps it is one which men will never be able to accomplish in a perfectly satisfactory manner. It is only necessary to contemplate that marvellous maze of star-streams around *Scorpio* and its neighbourhood, and to read the account which Sir John Herschel gives (in his *Cape Observations*) of the telescopic aspect of this region, to feel how far we are at present from being able rightly to interpret the mysteries of the Galactic circle.

The bolder and more striking features of that circle may, however, be studied with a better hope of their being successfully interpreted. A theory which will explain the gap in *Argo*, the wide break of one stream in *Ophiuchus*, the varying brightness of the principal stream in different parts of its length, and other features of this kind, may reasonably be sought for.

I have endeavoured in the inner circle of the figure to indicate a spiral which seems to me to account for the most striking features of the Milky Way.

Following that spiral round from the part where the two loops approach each other, we have the following relations :

First of all, the gap is explained by the fact that the two loops do not meet. Then, remembering that the spiral is supposed not to lie in one plane, but (as the contorted figure of the Milky Way obviously suggests) to have been swayed out of that plane by varying attractive influences, we see that where the line of sight is directed tangentially to either loop, the Milky Way might be expected to have greater width than elsewhere. This explains the fan-shaped expansions on each side of the gap. Then on each side of these expansions we see the Milky Way double, which obviously corresponds to the relations exhibited by the two loops. Following the wider loop, we see that the double part of the Milky Way on this side extends nearly through a complete semicircular arc. The Coal-sack is explicable as due to the apparent intercrossing of the two contorted streams which really are at different distances from the eye.* The break in the further branch seems readily explicable as due to the great distance of a portion of this branch. But here the theory derives a singular support from the actual relative brilliancy of different parts of the Milky Way in this neighbourhood. Every astronomer knows how strangely the light of the Milky Way varies in and near

* In the large maps of the S. D. U. K. the Milky Way is depicted near *Crux* and *Argo*, as if the object of the draughtsman had been to support my theory. In Sir John Herschel's drawing, however, there are no such varieties of brilliancy.

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*Cygnus*. The branch which extends from the Northern Coal-sack towards *Albireo* is at first far the brightest, and then fades off so much that in *Ophiuchus* it is wholly lost. The other branch, on the contrary, gradually increases in brightness, until in *Aquila*, and, further on, in *Sagittarius*, it forms the brightest part of the whole Milky Way. Now this part which is so very bright, corresponds to the part which my spiral brings so very near to the Sun.

Passing on to the termination of the second branch near *Cygnus*, it will be noticed how the spiral explains the strange extension of milky light from *Cepheus* towards the north pole.

Thence the stream is single, growing gradually fainter with increase of distance towards *Canis Minor* and *Monoceros*.

The spiral I have depicted seems so satisfactorily to account for several of the more striking features of the Milky Way, as to suggest the idea that it probably corresponds somewhat closely to the real figure of that star-stream. I am sensible, however, that many peculiarities remain unexplained by, though they are by no means opposed to, my theory. It must be remembered that any objections founded on a presumed equality of stars throughout the Milky Way, or of a general uniformity of distribution throughout the spiral stream, do not require to be met; because at the very beginning of this inquiry I have abandoned such hypotheses as inconsistent with existing analogies.

For example, there may be parts of this Milky Way so constituted, that if we were to remove further and further from them, we should see them gradually assuming the form of irresolvable nebulosity. But there may be other parts which would never assume that appearance, let their distance be what it might — the distribution and magnitude of the component stars being such that the stars would vanish through effect of distance, before the distances apparently separating them became evanescent.

I may add as a striking confirmation of a portion of these views, that among the lucid stars along the part of the Milky Way which lies nearest to the Sun, according to my view, are those which have been actually found to be nearest to us.

It must be understood that I regard the Milky Way as simply the condensed part of a spiral of small stars, which has been swayed into its present figure by the influence of large stars — the lucid stars seen in the Milky Way. The myriads of small stars not lying in or near the Milky Way, must yet belong to the same system, and in some instances seem to obey somewhat similar laws of aggregation. The nebulæ, so far as the evidence from probability extends, would appear to be groups formed from among those stars that have not fallen under the influence of the large stars which have brought the Milky Way spiral to its present figure. In the Magellanic clouds, we see the action of processes which have tended to form spherical clusters of enormous dimensions, in which both forms of aggregation are met with.

Why, in different parts of the sidereal system different pro-

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cesses of aggregation should have taken place, we cannot yet distinctly see. But some of the striking discoveries which have recently been made by astronomers afford promise that light will soon be thrown on these perplexing questions.

P.S.—If my views respecting the Milky Way are correct, it obviously follows that there are parts of the Milky Way where traces of annual parallactic displacement might be looked for amongst *telescopic stars*. One instance of such motion would force us to modify all the views at present accepted respecting the sidereal system.

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